

Bundle Image Interpolation (Matlab)

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Introduction

Removes core pattern in fibre bundle images by triangular linear interpolation. Calibration requires identifying location of each core, and so all images must be clearly resolved. Method is slower than simple spatial filtering but can deal better with broken cores or more complex reconstruction schemes (super-resolution etc.). It also may work better for coherent imaging where simple filtering does not preserve integrated intensity for each core.

Flat fielding involves capturing an image of uniform target (or simply shining a light through he bundle). The intensity value of each core is extracted from this flat field image and used to scale intensity values from each subsequent image. This accounts for differences between core transmission and, more importantly, any imperfections in finding the centre of each core.

Two methods of extracting core values have been implemented. The point method simply takes the pixel value at the detected centre of the core. This tends to lead to variations in intensity across the image, depending on where the core happens to sit relative to the pixel grid of the camera. Flat field correction is therefore critical.

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Usage

Use `bundle_calib` to generate a calibration from a flat image acquired through the fibre bundle. Then use `bundle_recon_interp` to reconstruct subsequent images.

Approach

Calibration Inputs: `calibImage`, `rawImage`, `flatImage`, core size range, bundle centre co-ordinates, bundle diameter

Reconstruction Inputs: `rawImage`

Calibration Stage (One-time)

1. Locate each core in `calibImage` using Hough Transform. Also store radius of each core.
2. Build Delaunay triangulation over the positions of the cores. This draws triangles between the core positions such that the angles of each triangle is maximised.
3. Specify a reconstruction grid (i.e. a 2D array of pixels.)

4. For each pixel in reconstruction grid, determine which triangle it sits inside.
5. Express each pixels location in barycentric co-ordinates. This gives its location as the inverse distance from each vertex of the enclosing triangle. The Cartesian location of these three cores is also stored.
6. [Optional] Extract intensity of each core in flatImage (see below for details of methods). Store these flat field core values (R_i).

Reconstruction Stage (For each image)

1. Extract intensity of each core.
 - a. Point Method: Read-off pixel value at centre of core
 - b. Area Method: Average pixel value over area of core (assume a circle centred on core location).

2. [Optional] Correct core intensity by dividing by recorded flat field core value.

$$C'_i = C_i/R_i$$

3. For each pixel on reconstruction grid, interpolate between intensities of three cores making up enclosing triangle. This can be fast as we have pre-computed the Barycentric co-ordinates, and so the interpolated value for core i is simply

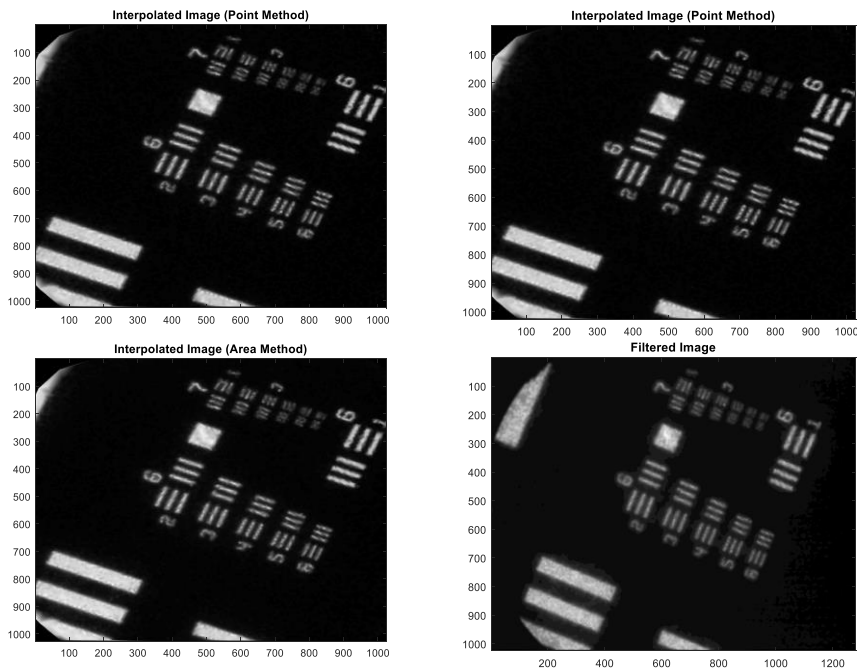
$$I_i = \sum_{c=1}^3 b_{i,c} C'_i$$

where $b_{i,c}$ is the barycentric co-ordinate for surrounding core c of reconstruction pixel i . This can be performed using fast matrix maths.

4. Crop reconstructed image with a circular mask to remove edge artefacts.

Example Results

USAF resolution target back-illuminated by LED and placed in direct contact with Fujikura HD fibre bundle (30,000 cores, approx. 3 microns core spacing)



Functions

build_tri:	Performs calibration necessary to reconstruct fibre bundle image by triangular linear interpolation
bundle_calib:	Calibration for reconstruction of fibre bundle images by linear triangular interpolation. Locates cores, performs Delaunay triangulation, determines enclosing triangle for each reconstruction pixel and expresses pixel location in barycentric co-ordinates.
bundle_recon_interp:	Reconstructs image acquired through fibre bundle by interpolating between cores.
core_values_area:	Returns intensity from each bundle core by integrating over area of core
core_values_pt:	Returns intensity at centre pixel of each core, with optional Gaussian filter
find_core:	Identifies cores in a fibre bundle image using <code>imfindcircles</code>
recon_tri_interp:	Reconstructs fibre bundle image by triangular linear interpolation. Requires a previous calibration using <code>build_tri</code> which returns <code>tri</code>

To Do

Some work to do on core finding as this is not always robust. Previous work on using `imregionmax` looked promising.

For fluorescence imaging, background subtraction could also be implemented within the algorithm (rather than simply subtracting a background image post-recon).